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Is there a physical basis for the Cohesive Energy Rule of vacuum arcs?

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The Cohesive Energy Rule for vacuum arcs [1] describes an empirical relationship between the cathode material and the arc burning voltage, namely, that the burning voltage depends linearly on the cohesive energy according to $V=V_0+A\ E_{CE}$, where V_0~14.3 V and A~1.69 V/(eV/atom) for the experimental setup used in [2]. Because the self-adjusting burning voltage determines the power input for a given arc current, which is usually determined by the impedance of the arc circuit, one can derive numerous correlations between the cohesive energy (a fixed solid state quantity) and plasma parameters, including electron temperature and mean ion charge state. Although the Cohesive Energy Rule and the derived relationships show surprisingly good agreement with experiments, it is only a rule, not a physical law. In this contribution, the physical basis for the rule will be discussed. Two arguments are brought forward. First, many physical parameters show periodicity as expressed in Periodic Tables of the Elements, and therefore periodicity shown by one quantity (e.g. the cohesive energy) can be used as a proxy for the periodicity exhibited by other quantities (for example, ionization energies). The second reason why the Cohesive Energy Rule works so well is that it is based on the first law of thermodynamics, energy conservation, in conjunction with a consideration of how the energy input is distributed. In order to accomplish the phase transition from the solid to the plasma, energy must be invested, and the cohesive energy represents the energy needed to reach the vapor phase. This concept will be illustrated by examples.

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[1] A. Anders, Appl. Phys. Lett. 78 (2001) 2837
[2] A. Anders, B. Yotsombat, and R. Binder, J. Appl. Phys. 89 (2001) 7764.